TECHNOLOGY NEEDS/OPPORTUNITIES STATEMENT

UNDERSTAND AND QUANTIFY WATER MOVEMENT IN THE VADOSE ZONE USING UNCONTAMINATED FIELD SITES

Identification No.: RL-SS30
Date: September 2001

Program: Environmental Restoration
OPS Office/Site: Richland Operations Office/Hanford Site
Operable Unit(s): Broad need potentially applicable to multiple operable units.
PBS No.: RL-SS04 (RL-VZ01)
Waste Stream: Disposition Map Designations: ER-04 [technical risk score 3], ER-14 [technical risk score 5], ER-03 [technical risk score 3]
TSD Title: N/A
Waste Management Unit (if applicable): N/A
Facility: N/A

***Priority Rating*:**

This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

X 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

***Need Title*:** Understand and Quantify Water Movement in the Vadose Zone using Uncontaminated Field Sites

Need/Opportunity Category: Technology Need

***Need Description*:** This need addresses specific technical gaps identified in the scope of the Groundwater/Vadose Zone Integration Project (Integration Project) at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions, including decisions related to long-term stewardship, are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where a specific technology need can be defined separately from an "integrated" need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG

Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

The rate of movement of contaminants from buried waste through the vadose zone to groundwater is presently not well documented for Hanford Site conditions. Neither the chemical or physical mechanisms for flow and transport in the vadose zone are well understood. Prior to recent efforts by the River Protection Project (RPP) Tank Farm Vadose Zone Project to characterize the S-SX and B, BX-BY tank farms, few boreholes in the tank farm area have been cored and analyzed for both hydraulic properties and chemistry (Freeman-Pollard et al., 1994; Myers et al., 1998) and rates of vadose zone migration are still indeterminate for most, if not all of the contaminants of concern. Moreover, little is known about the physical and chemical processes that are most significant over protracted contact times of the waste with the sediments in the vadose zone (Jones et al., 1998) and this has led to predictions of flow and transport that are plagued with large uncertainties. These processes may differ significantly from short term ones studied in the laboratory. Within this context, the effects of extreme waste chemistry, unsaturated water conditions and complex, geologically controlled water flow paths add to the uncertainty of contaminant movement (Conway et al., 1997; Conway et al., 1998). Without such information, little can be said about the long-term stability of the in-ground contaminant inventory; has it been immobilized or is it available for transport? Recent groundwater monitoring reports (see for example, Johnson and Chou, 1998; Hodges, 1998; Narbutovskih, 1998) have also highlighted some of the uncertainties in vadose zone/groundwater interactions.

Rates of transport to groundwater may range from decades to thousands of years, depending on the nature of the waste and the amount and location of the water sources that mobilize waste and carry it to the water table. No direct measurement of net water infiltration (the primary driver for fluid migration in the vadose zone) has been made at any Hanford waste site (Smoot et al. 1989, Ward et al. 1997). In addition, accelerated flow paths (channels etc.) may funnel contaminants more rapidly than current hydrologic models predict (Conaway et al. 1997, 1998) via preferred pathways caused by geologic features, by dissolution of sediments from extreme wastes, or unstable wetting fronts. Fast flow pathways may be tortuous and of limited horizontal extent so that locating them with widely spaced boreholes will be difficult. Temporal variations in vadose zone fluxes are also expected as a results of variations in surface-controlled net water infiltration, spatially distributed preferential flow paths, and temporally/spatially discrete waste-water discharges. These temporal fluxes are important and are assumed to cause observed transient peaks in groundwater contamination levels. Elucidating these phenomena is important to the understanding of the nature and extent of contamination determined during field characterization at contaminated sites and subsequently, forecasting future extent of contamination during and after remediation.

The primary technical gap associated with transport in the vadose zone is an insufficient understanding of uncertainties in source terms, geohydrologic properties, and chemical interactions that combine to make current modeling of contaminant transport in the Hanford vadose zone questionable. The sediments beneath waste sites at Hanford are known to be highly heterogeneous (e.g., interbedded sand, silts and gravels). These heterogeneities, coupled with temporal and spatial variations in net water infiltration (via past liquid discharges, water line leaks, meteoric

sources, etc.) and variable chemical interactions complicate description and understanding of contaminant transport, often making an evaluation of transport at contaminated sites ambiguous.

Specific issues that need to be addressed to resolve this technical gap include the following:

- Information on the nature and extent of preferred flow paths in Hanford vadose zone sediments is needed. Specific information needed includes the following. A determination of which geologic and lithologic features area associated with preferred flow paths and under what moisture conditions they function as conduits is needed. Techniques to determine the length scales over which preferred flow paths are present at Hanford. Information is needed to determine which waste chemistries are conducive to formation of preferred flow paths and what hydrochemical reactions are most important in the field and to what extent they control in situ flow velocities and direction. Information to determine to what extent laboratory-derived reaction parameters are descriptive of geochemical phenomena occurring in preferred flow paths and, if differences are observed, what in situ features cause the differences. In addition, information is needed to determine whether fast radionuclide migration pathways through the vadose zone exist and, if so, their origin. Appropriate model formulations that include the impact of preferential flow pathways and the near-field impacts of thermal and pressure (advective) enhancements in predictive flow and transport models are also needed.

- Techniques are needed to determine the frequency of preferred flow paths in the Hanford vadose zone as well as an understanding of the geologic and lithologic features and moisture content associated with the flow paths. Documentation of the distribution of the flow pathways will provide a basis for more realistic predictions of early arrival of contaminant plumes. Quantification of the flow pathways may help explain why mobile elements such as technetium-99 and nitrate, are being discovered in elevated concentrations in some groundwater wells near tank farms and not in others (Science Need RL-WT035-S).

- Information is needed to determine the extent to which hydrochemical reactions that create preferred pathways influence the in situ flow velocity and direction. These reactions influence the in-situ flow velocity and direction. Parameters are needed that clearly define the interactive role of waste chemistry and hydrologic reactivity when physically hot brine interacts with Hanford sediment and alters the hydrologic flow regime (Science Need RL-WT035-S).

- Information is needed to determine the best field-scale values and statistics for hydraulic and geochemical parameters and the approach to best derive and transfer these parameters. There is a need to develop approaches that best derive and transfer these parameters to other locations and depths in the Hanford vadose zone (Science Need RL-WT035-S).

- Information is needed to determine net water infiltration for a given waste site at Hanford. The variability may include vegetation dynamics (resulting from disturbances, fires, drought) and its impact on the local and regional recharge rates that ultimately control contaminant migration rates. The spatial and temporal variation of the water infiltration rates, can drastically affect the amount of contaminant moving to groundwater from a given waste site. Such information has been lacking in the predictive modeling of risk and dose from Hanford waste areas and the impact of these variation need to be documented. (Science Needs RL-WT035-S and RL-WT044-S).

- Means to quantify the distribution of recharge throughout the Hanford Site as well as through an individual waste site, the variability (uncertainty) possible in the distribution of recharge, and the time delay between recharge through the land surface and that into the water table are needed (Science Need RL-WT044-S).

- The interaction of the factors that effect water recharge variables across a sparsely vegetated landscape over long times (thousands of years) need to be understood and incorporated into estimates of long-term rates of water infiltration (Science Need RL-WT044-S).

- The impact of future land and water use and potential climate changes on water infiltration needs to be understood and incorporated into modeling efforts to predict the transport of contaminants (Science Need RL-WT044-S).

Schedule Requirements:

Earliest Date Required: 8/1/99

Latest Date Required: 9/30/05

The Integration Project S&T roadmap (DOE/RL-98-48, 2000) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with water movement in the vadose zone is needed in the FY02 to FY03 timeframe to meet these objectives.

***Problem Description*:** This need falls under the Vadose Zone Technical Element within the S&T Endeavor. The Vadose Zone Technical Element is intended to address and resolve scientific problems related to the leakage of radioactive and hazardous wastes into Hanford soils and sediments. The objective of the Vadose Zone Technical Element is to enhance protection of human health and the environment by providing 1) improved models, measurements, and data to predict contaminant migration and provide warning of potential surface or groundwater contamination before problems arise; 2) scientific rigor to system assessment and PA models as they are developed, reviewed, and implemented; and 3) scientific support for selection of the most safe, efficient, and effective remedial actions and site closure activities. An implicit goal of

this research is to provide scientific and regulatory credibility to DOE's environmental management decision-making process.

The scope of this technical element encompasses the unsaturated zone beneath the Hanford Site. The geographic focus is on areas that (1) underlie liquid waste disposal sites; (2) have the potential for leaks or leaching; and (3) have experienced past leaks and spills. Also included are selected areas away from the focus areas, such as areas representative of background conditions, and areas that have the potential to become contaminated in the future.

Specific topics for this need include (1) a comprehensive data set with clear boundary conditions and known source functions to validate conceptual and numerical models of water movement through the Hanford vadose zone; (2) procedures for scaling up laboratory-derived parameters (e.g., chemical reaction parameters, hydraulic properties, etc,); and (3) input to site-specific and site-wide assessments that provide realistic assessment of plume migration rates in the vadose zone sediments at Hanford

Benefit to the Project Baseline of Filling Need: The application of surface barriers and other remediation strategies currently planned for the Hanford Site depends on a clear understanding transport processes in the vadose zone. Confidence in predicting contaminant travel times at treated or covered sites will be enhanced by implementing this activity. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

***Functional Performance Requirements*:** The techniques applied or information that is obtained must delineate water infiltration rates or relate water movement to Hanford waste site geology and surface features such that the information can be applied toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project.

Work Breakdown Structure (WBS) No. : 1.4.03.4.4 ***TIP No.:*** TIP-0013

Relevant PBS Milestone: PBS-MC-042

***Justification For Need*:**

Technical: There is an insufficient understanding of uncertainties in source terms, geohydrologic properties, and chemical interactions that combine to make current modeling of contaminant transport in the Hanford vadose zone questionable. The sediments beneath waste sites at Hanford are known to be highly heterogeneous (e.g., interbedded sand, silts and gravels). These heterogeneities, coupled with temporal and spatial variations in net water infiltration (via past liquid discharges, water line leaks, meteoric sources, etc.) and variable chemical interactions complicate description and understanding of contaminant transport, often making an evaluation of transport at contaminated sites ambiguous.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety & Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Potential Life-Cycle Cost Savings of Need (in $000s) and Cost Savings Explanation: The estimated life-cycle cost savings associated with filling this need is $200M. This estimate is based on an assumed savings of 5% of the total Hanford remediation life-cycle cost of >$5B. Estimated savings are due to information and data gained by filling this need that supports decisions for cost effective remediation and long-term stewardship.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in "Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment" (DOE 1998).

Other: None.

Current Baseline Technology: N/A

End-User: Richland Environmental Restoration Project

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DOE End-User/Representative Point-of-Contact: John G. Morse, DOE-RL, (509) 376-0057

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